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ABSTRACT

Reported is an investigation of: (1) the effect of teacher wait-time on science achievement; and (2) the difference in the achievement of children at the formal stage and those at the concrete stage of cognitive development. Teacher wait-time was defined as the length of the pause preceding any teacher utterance. The sample consisted of 23 intact classes of children from grades 5, 6 and 7 in Australian schools. Three treatment groups were used: (1) wait-time greater than 2-7 seconds; (2) wait-time greater than one second but less than 2-7 seconds; and (3) wait-time less than or equal to one second. Science achievement was measured with paper and pencil tests based on physical science concepts taught in the study. Results showed that the extension of teacher wait-time produced desirable changes in science achievement for fifth, sixth, and seventh graders. (HM)

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The Effect of an Extended Teacher Wait-Time on Science Achievement

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The Effect of an Extended Teacher Wait-Time on Science Achievement.

INTRODUCTION

Studies conducted by Rowe (1974a) have shown wait-time to be an important variable in determining the quantity and quality of child discourse that occurs in science lessons. When teachers are able to utilize a wait-time in excess of three seconds, significant improvements, which were indicative of increased child thought, were observed in child verbal behavior. The use of an extended wait-time produced an improved learning environment that should have a positive influence on science achievement.

PROBLEM

This study investigated the effect of an extended teacher wait-time on science achievement. Teacher wait-time was defined as the length of the pause preceding any teacher utterance. The two questions addressed in the study were:

1. Is science achievement higher when instruction incorporates a teacher wait-time greater than 2.7 seconds?
2. Is the increase in science achievement greater for children at the formal stage than for those at the concrete stage when a teacher wait-time greater than 2.7 seconds is utilized?

RATIONALE

Rowe (1974b) stated that there was evidence of wait-time being a threshhold phenomenon, with a lower limit of 2.7 seconds. If teachers did not maintain a mean wait-time in excess of the threshhold value, the

desirable changes in student behavior were not evident. Of the improvements reported by Rowe (1974a), the following suggest that science achievement could be increased when an extended wait-time is used:

1. The length of student responses increased.
2. Failure to respond decreased.
3. The incidence of speculative responses increased.
4. The incidence of child-child comparisons of data increased.
5. The incidence of evidence-inference statements increased.
6. The incidence of questions asked by students increased.

An outcome reported by Lake (1973) is also related to science achievement. Lake found that student responses became cognitively more complex when an extended wait-time was used.

As children explain something orally, pauses which often exceed three seconds duration are commonly observed. According to Rochester (1973), the duration of the pauses increased with the difficulty the child experienced making the explanation and the pause frequency was dependent on interaction between speakers. It follows that longer and more frequent pauses can be expected in child talk when the use of higher level thinking is required. Ample opportunity is thus provided for the unwary teacher to interrupt child talk and subsequent cognitive activity. If the classroom teacher is to extend teacher wait-time beyond 2.7 seconds, the number of such interruptions should be minimized, greater cognitive activity should occur and higher science achievement should result.

Children at the formal stage of cognitive development are able to use more powerful modes of thinking than children at the concrete stage. Through the use of hypothetico-deductive reasoning and propositional thinking, children at the formal stage should benefit from additional

thinking time to construct explanations and questions of higher cognitive complexity. This is not to suggest that children at the concrete stage will not benefit from an increase in wait-time, but to anticipate greater relative benefits for children at the formal stage.

PROCEDURES

The sample consisted of twenty-three intact classes of children from grades five, six and seven classes in eleven Australian schools. Although it was not possible to randomly select schools or teachers because of constraints imposed by the state education authority, the sample was assessed to be representative of senior grades in urban primary schools in Australia.

Design

The experimental design utilized a blocking technique to pair schools so that variables such as the number of participating classes in a school could be controlled. Schools from each blocked pair were randomly assigned to two treatment groups.

A sequence of twenty lessons based on Elementary Science Study topics Ice Cubes, Colored Solutions, and Clay Boats was taught over a thirteen week period of time. Prior to the treatment phase the mean wait-time for all teachers in the study was 0.5 seconds. During the thirteen activity treatment phase one group of teachers (n=13) endeavored to extend their wait-time beyond three seconds, while another group (n=10) maintained a wait-time between 0.5 seconds and 1.0 second. In fact, three treatment groups were defined because some teachers in the extended wait-time group could not attain the criterion wait-time that was set at 2.7 seconds. These groups, representing the treatments of a quasi-

experimental design, were:

1. wait-time greater than 2.7 seconds (n=8).
2. wait-time greater than 1.0 second but less than 2.7 seconds (n=5).
3. wait-time less than or equal to 1.0 second (n=10).

To compare the effects of wait-time manipulation, the mean achievement scores for each class were used as the unit for statistical analysis.

To examine possible unequal treatment effects among learners identified as concrete or formal operational, all children categorized as formal operational (n=36) and a random selection of children at the concrete stage were identified. The selection process ensured that the number of formal and concrete subjects from each class was equal.

The thirty-six children at the formal stage were distributed among fifteen classes, the number per class ranging from one to seven. Due to this unequal distribution among classes, the analysis of results was based on two treatment groups:

1. those children receiving a wait-time mode of instruction above 2.7 seconds (n=20).
2. those children receiving less than criterion wait-time instruction (n=16).

Individual achievement scores on each test were chosen as the unit for statistical analysis for this question.

Independent Measures

Two independent variables were measured in this study, teacher wait-time and cognitive development of children.

Teacher Wait-Time

As it was defined in this study, wait-time embraced all utterances

that occurred in an instructional sequence. The following situations were relevant to the measurement of teacher wait-time:

1. when child dialogue is followed by a teacher utterance.

2. when a teacher utterance is followed by another teacher utterance.

Discourse that was extraneous to the lesson objectives, such as discipline or classroom organizational moves, was not considered in the analysis.

Each lesson was recorded on a portable tape recorder attached to the teacher's waist. At a later time the duration of the pauses was measured with a servo-chart recorder with an accuracy of one-tenth of a second. The arithmetic mean of the relevant pauses was then computed for each lesson.

Cognitive Development

The level of cognitive development, a stratifying variable in the analysis of question two, was measured with a written test administered after the final achievement test. A test devised by Tisher and Dale (1975) was modified for this purpose. In a separate study, the modified test was validated against a set of tasks administered to children, individually, in an interview mode. The tasks used in the validation study were Equilibrium in the Balance, Colorless Chemicals (Inhelder and Piaget, 1958) and Stickmen (Karplus and Peterson, 1970). If the children achieved at the formal level on at least two of the three tasks, they were categorized at the formal operational level. This classification was then compared with that obtained on the written test. The correlation between the categorizations (Table I) was statistically significant ($\phi = 0.6$, $p < 0.001$). Although there was only seventy-eight per cent agreement obtained on the two measures, the data obtained indicated that it was most unlikely that

a child at the concrete level would be rated formal on the written test. As a consequence, the test was suitable for identifying children at the formal operational level, but was not as useful for identifying those at the concrete operational level. The validation results indicated that a significant proportion of children categorized as concrete may actually be at the formal level.

The Kuder-Richardson Formula 20 reliability for the revised test was 0.7.

TABLE I

Validation Results for Modified Tisher-Dale Test

	F_t	C_t
F_i	30	17
C_i	2	38

$\phi = 0.6$ $\chi^2 = 32.1$ $p < 0.001$

F_t students categorized as formal on test.

F_t students categorized as formal on interview.

C_t students categorized as concrete on test.

C_i students categorized as concrete on interview.

Dependent Measures

Science achievement was measured with written tests on three occasions. Each test contained items based on the concepts taught in the lesson sequence. A high proportion of the items required children to use modes of thinking at the application, analysis or synthesis level of the taxonomy (Bloom et al., 1956), or generalization to solve problems set in contexts not previously encountered.

The Kuder-Richardson Formula 20 reliability was 0.6, 0.6 and 0.7 for test 1, test 2, and test 3 respectively. Test 1 was administered prior to the treatment phase, test 2 midway through it, and test 3 at the conclusion of the lesson sequence.

RESULTS AND DISCUSSION

Question One

The mean scores for each treatment are reported in Table II. Since the test scores were percentages, an arc-sine transformation (Myers, 1972, p.77) was used before conducting MANOVA. The transformation did not affect the outcome of the experiment as almost identical probability statements are obtained when raw data is used in the analysis.

Three science achievement scores and two gain scores (test 2 - test 1; test 3 - test 1) constituted the dependent variables in the analysis. The only independent variable was treatment which had three levels.

Two planned orthogonal contrasts were used to test differences in achievement scores and gain scores for the treatment groups. The first contrast compared the performance of the extended wait-time group with the average performance of the other two groups. The second contrast

TABLE II

Group Means on Achievement Tests

	Test 1	Test 2	Test 3
Group 1	70.13	71.98	71.80
Group 2	63.14	62.56	62.99
Group 3	67.30	58.18	59.67

Group 1 wait-time >2.7 seconds.

Group 2 2.7< wait-time >1.0

Group 3 wait-time >1.0 seconds.

TABLE III

Orthogonal Contrasts of Group Performance

on Achievement Tests

Contrast: $\bar{X}_{1.} - \frac{\bar{X}_{2.} + \bar{X}_{3.}}{2}$			
	Test 1	Test 2	Test 3
$MS_{between}$	0.011	0.089	0.071
MS_{error}	0.011	0.010	0.008
F	1.00	9.16	9.00
p	0.33	0.007	0.007
Contrast: $\bar{X}_{2.} - \bar{X}_{3.}$			
$MS_{between}$	0.006	0.007	0.004
MS_{error}	0.011	0.010	0.008
F	0.60	0.69	0.49
p	0.45	0.41	0.49

compared the performance of the intermediate wait-time group with that of the short wait-time group. Achievement scores and gain scores were analyzed in separate analyses.

The analysis of achievement scores indicated that for test 2 and test 3, the group of classes that had received extended wait-time instruction attained significantly higher mean scores than the average performance of the other two groups ($p < 0.05$). The orthogonal contrast $\bar{X}_{2.} - \bar{X}_{3.}$ was not significant for any occasion of testing ($p > 0.05$). The univariate F ratios for the analysis are contained in Table III.

This statistical analysis provided support for the hypothesis that classes receiving extended teacher wait-time modes of instruction achieve at a higher level than those receiving instruction that incorporates a teacher wait-time less than 2.7 seconds. It also appears that for an increased wait-time to be effective it is necessary to attain a threshhold of approximately 2.7 seconds. The group that received an intermediate wait-time did not attain significantly higher achievement scores than the short wait-time group.

The analysis of gain scores (Table IV) provided an indication of the effect of wait-time throughout the treatment phase. The F ratio obtained for the contrast $\bar{X}_{1.} - \frac{\bar{X}_{2.} + \bar{X}_{3.}}{2}$ was not significant for gain 1 (test 2 - test 1; $p = 0.08$), but was significant for gain 2 (test 3 - test 1; $p = 0.04$). The orthogonal contrast $\bar{X}_{2.} - \bar{X}_{3.}$ was not significant on either occasion ($p > 0.05$).

The gain score analysis indicated that the differences between the treatment groups were not significant until the final occasion of

TABLE IV

Analysis of Variance of

Achievement Gains

Contrast: $\bar{X}_{1.} - \frac{\bar{X}_{2.} + \bar{X}_{3.}}{2}$		
	Gain 1	Gain 2
$MS_{between}$	0.038	0.027
MS_{error}	0.011	0.006
F	3.35	4.85
p	0.08	0.04
Contrast: $\bar{X}_{2.} - \bar{X}_{3.}$		
$MS_{between}$	0.026	0.020
MS_{error}	0.011	0.006
F	2.31	3.62
p	0.14	0.07

testing. Whereas the use of an extended wait-time produces almost immediate observable changes in verbal behavior, changes in learning outcomes only become evident over a longer period of time, in this case, thirteen lessons.

Question Two

The modified Tisher-Dale test was administered to 733 children. Using the categories suggested by Tisher and Dale (p.9), the children at the formal stage of development were identified. These results are summarized in Table V.

TABLE V

Distribution of Scores Obtained on Modified Tisher-Dale Test

Score Range	Number of Children	Level of Development
24 - 20	36	early formal
19 - 15	217	concrete
14 - 10	306	concrete
9 - 5	158	concrete
4 - 0	16	concrete

A summary of the data used in the analysis of question two is contained in Table VI. Differences in the mean achievement for each group were tested for each occasion of testing using an analysis of variance with treatment and developmental level as independent variables. As for the analysis of question one, the data were transformed with an

TABLE VI

Cell Means on Achievement Measures

	Test 1		Test 2		Test 3	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Concrete	72.70	80.94	70.90	67.11	76.10	59.11
Formal	77.28	81.64	81.64	72.25	80.14	62.82

Group 1 wait time >2.7 seconds

Group 2 wait-time <2.7 seconds

arc-sine transformation.

The main interest in this analysis was the magnitude of F for the interaction between treatment and developmental level for test 2 and test 3. A significant F would provide support for the position presented in the rationale, that children at the formal stage would benefit more from an extended wait-time than those at the concrete stage. The F ratio for the main effect, treatment, is of little interest since the analysis for question one provided similar information based on class means. The F ratio for the other main effect, developmental level, provided a test of the significance of the difference in performance between children at the concrete and formal developmental levels.

The results of this analysis (Table VII) indicated that the interaction between treatment and developmental level was not significant on any occasion of testing ($p > 0.05$). The analysis supports an hypothesis of no interaction of developmental level with teacher wait-time. This interpretation should be regarded as tentative because the problems of obtaining valid measures of developmental level were such that the absence of an interaction could be explained in terms of high achievement by children incorrectly categorized at the concrete level. Further research is required to find a satisfactory answer to this question.

The analysis of main effects confirmed that the extended wait-time group achieved at a higher level than the short wait-time group on test 2 and test 3 ($p < 0.05$). Although the group of children at the formal stage attained higher achievement scores in each test than the group at the concrete stage, the difference was only significant for test 2 ($p = 0.003$). Considered together, these results suggest that

TABLE VII

Analysis of Variance on Achievement Scores

for Main and Interaction Effects

Test 1	df	MS	F	p
Treatment (T)	1	0.101	5.60	0.02
Developmental Level (D)	1	0.020	1.13	0.29
Interaction (T x D)	1	0.009	0.48	0.99
Error	68	0.018		
Test 2				
Treatment (T)	1	0.103	6.02	0.02
Developmental Level (D)	1	0.164	9.54	0.003
Interaction (T x D)	1	0.022	1.31	0.25
Error	68	0.017		
Test 3				
Treatment (T)	1	0.634	29.32	0.001
Developmental Level (D)	1	0.035	1.64	0.20
Interaction (T x D)	1	0.001	0.03	0.99
Error	68	0.022		

the use of an extended teacher wait-time was as effective for children at the concrete stage as for children at the formal stage.

IMPLICATIONS

Teacher wait-time, proposed by Lake as a modification to the original definition (Rowe, 1974a), provided teachers with direct control over the length of the relevant pause. Since child talk could not reduce teacher wait-time, teachers needed only to pause for three to five seconds to effect an extended teacher wait-time. Of the thirteen teachers who endeavored to attain the criterion, eight were successful. Only two of the others appeared to make a serious effort to extend their wait-time beyond the criterion. However, due to well established styles of teaching and a comparatively short time in which to change, they were unable to attain a mean of 2.7 seconds. It was apparent that the remaining teachers needed to be convinced of the merits of an extended wait-time before attempting a change of the required magnitude. It was not possible to provide them with such evidence because of the effect on the internal validity of the study. Constraints of this type would not be required in pre-service and in-service programs and the modified definition should be readily implemented by all teachers.

In this study, child wait-time, the length of the silent pause preceding a child utterance, was not manipulated or measured. Since, in materials-centered science, much of the verbal interaction occurs in the absence of the teacher, child wait-time is likely to be important in determining the quality of the discourse that occurs in groups. Despite problems that may be encountered in ensuring that children pause for sufficient time, the effect on verbal and cognitive outcomes of

extending child wait-time should be studied.

An important outcome in any science program is the development of process skills. At the age level of the children involved in this study the development and use of integrated processes is often advocated. While the use of an extended wait-time alone is unlikely to lead to higher process skill attainment, its use in conjunction with other teacher variables, such as the use of higher level questions, should be investigated.

CONCLUSION

The extension of teacher wait-time produced desirable changes in science achievement for children in grades five, six and seven classes. Specifically, an increase in the level of achievement occurred when the teacher was able to attain a mean wait-time in excess of 2.7 seconds. The use of an extended teacher wait-time did not alter the relative achievement of children at the formal stage compared with those at the concrete stage.

This study provided further evidence of the importance of wait-time as a teaching variable. Teacher educators should advocate its use as an essential component of effective science teaching.

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